EFFECTS OF TEMPERATURE AND PARENTAL AGE ON THE LIFE CYCLE OF THE DARK MEALWORM, *TENEBRIO OBSCURUS* FABRICIUS*

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Arendsen Hein (1923) found that the optimal temperatures for both the yellow mealworm, *Tenebrio molitor,* and the dark mealworm, *T. obscurus,* were between 25° to 27.5° C. He counted 10 to 14 molts for *T. molitor,* but he did not observe the number in *T. obscurus.* With proper food, temperature and humidity, the average larval period lasted from 6 to 8 months for both species. Cotton and St. George (1929) reported that the dark mealworm had an egg stage which varied from 4 to 7 days at 80° to 88° and from 17 to 18 days at 65° F. The pupal stage of this species was found to be 7 days at 77° to 78° and 20 days at 65° F.

The number of larval molts may also vary with temperature. Ludwig (1956) found 11 to 15 and 15 to 23 larval molts for *T. molitor* at 25° and 30° C., respectively. Tracey (1958), working with this species, observed that at 25° and 30° C. at a relative humidity of 75 per cent, the duration of the larval stage and the number of larval molts were greater at the higher temperature. Larvae obtained from eggs laid by beetles 1 week after emergence had an average larval life of 153.7 days and had 13.7 molts at 25°; while at 30° C., these values were 168.0 and 15.8, respectively.

Parental age may also affect the duration of the life cycle. Ludwig (1956) observed that in *T. molitor* the length of larval life was diminished in the progeny of older beetles. In this species, Tracey (1958) found that offspring from young parents had a longer larval period than those from old parents. At 25° C. these values were 153.7 and 143.9 days, respectively.

Since there is a lack of information regarding the life cycle of the dark mealworm, *T. obscurus,* it was decided to rear this

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insect individually at each of three temperatures, 20°, 25° and 30° C. In some experiments both humidity and parental age were controlled. Observations were made on the duration of the various stages of the life cycle, the number of molts and the growth rate in the different environments.

MATERIAL AND METHODS

Adults, collected within 24 hours of emergence, were kept in a specimen dish containing chick growing-mash. When eggs were desired, the beetles were transferred to white flour. Water was supplied by a water bottle plugged with moist cotton. Eggs were collected daily by sifting the flour.

In the first phase of the experiments, the parents were kept at the same temperature as the offspring, 20°, 25° or 30° C. The eggs, as well as the various stages of the life cycle, were maintained in a desiccator, the base of which contained a saturated solution of NaCl (relative humidity 75 per cent). At hatching, larvae were placed individually in 15 ml. vials with a small amount of chick growing-mash. The larvae were examined daily for molts and the exuviae removed. Observations were made on the length of the preoviposition period, the duration of each instar, and of the larval, pupal and adult stages.

TABLE I

EFFECTS OF TEMPERATURE ON THE LIFE CYCLE OF *T. obscurus*.
(A) at 75 per cent relative humidity
(B) outside the humidifier
Values are given with their standard errors.

	Number of larvae	Duration of egg stage in days	Duration of larval stage in days	Number of larval molts	Duration of pupal stage in days	Duration of adult life in days
20°C.	A. 41	11.56	374.51 ± 20.53	17.29 ± 0.34	13.14 ± 0.22	19.81 ± 1.61
	B. 222	7.02*	204.77 ± 1.67	13.41 ± 0.05	13.05 ± 0.05	31.70 ± 0.94
25°C.	A. 81	6.21	213.40 ± 3.11	16.37 ± 0.11	8.27 ± 0.06	17.37 ± 0.70
	B· 213	6.75	194.06 ± 1.30	15.00 ± 0.05	8.40 ± 0.04	33.91 ± 1.67
30°C.	A. 26	4.00	230.77 ± 4·71	18.46 ± 0.27	6.18 ± 0.12	12.29 ± 0.78
	B. 207	7.01*	218.38 ± 1.74	16.81 ± 0.07	6.29 ± 0.04	14.97 ± 0.44

* Eggs laid and hatched at 25°C

Additional experiments were performed at each temperature. The insects were not kept at 75 per cent relative humidity, but they were kept in vials and the food moistened by adding a drop of tap water several times a week to each vial. In these experiments, eggs were collected from beetles kept at 25° C. and allowed to hatch at this temperature. The larvae, within 24 hours of hatching, were then placed individually in vials and allowed to develop at 20°, 25° or 30° C. In these experiments, parental age was controlled with series being set up at each temperature from parents 7 to 10, 16, 23 and 42 days after emergence. The same observations were made as before; and in addition, the growth rates were determined by weighing 10 insects from each group individually at weekly intervals.

OBSERVATIONS

The preoviposition periods were 9, 6 and 4 days at 20°, 25°

TABLE II

PROBABLE SIGNIFICANCE OF DIFFERENCES FOR THE VARIOUS STAGES AT 20°, 25° AND 30°C., COMPARING THOSE IN THE HUMIDIFIER (A) WITH THOSE OUTSIDE THE HUMIDIFIER (B).

	Difference between means (A) and (B)	Difference/ Standard error of difference* (t value)
Duration of larval stage		
20°C.	169.74 days	8.25
25°	19.34 "	5.76
30°	12.39 "	2.48
Number of larval molts		
20°C.	3.88	11.41
25°	1.37	11.42
30°	1.65	5.89
Duration of pupal stage		
20°C.	0.09 days	0.39
25°	0.13 "	1.86
30°	0.11 "	0.85
Duration of adult life		
20°C.	11.89 days	6.43
25°	16.54 "	8.99
30°	2.68 "	2.98

* Ratios of 2 or more are considered significant.

and 30° C., respectively. At these temperatures and at 75 per cent relative humidity the embryonic periods were 11.56, 6.21 and 4 days, respectively (table I).

As shown in the table, the larval period and the number of larval molts were greater for insects reared at 75 per cent rela-

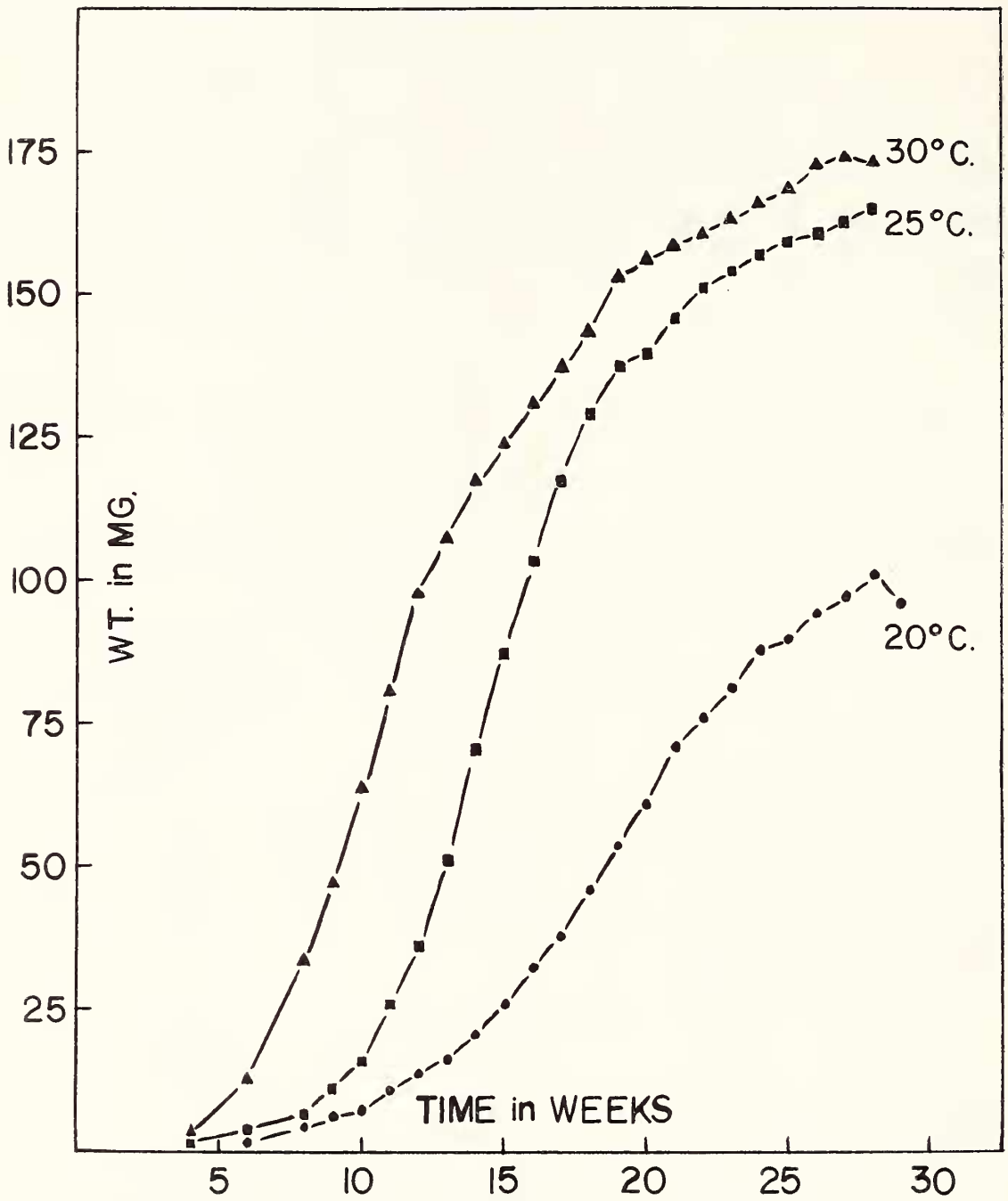

FIG. 1. Growth rate of larvae of *T. obscurus* at 20°, 25° and 30°C.

tive humidity than for those kept outside of the humidifier. Furthermore, the duration of adult life was considerably reduced for those kept in the humidifier. At each temperature the pupal period was the same in the two series. The optimal

temperature was 25° C., the larval period being shortest at this temperature. A temperature of 30° C. greatly reduced adult longevity. Pupal life was shorter, the higher the temperature.

The range in the number of larval molts was smallest at 25° C., being 13 to 19. The corresponding values at 20° and 30° C. were 12 to 22 and 15 to 24, respectively. The average number of molts was greater at the higher temperatures, being 14.01,

TABLE III

EFFECT OF PARENTAL AGE ON THE LIFE CYCLE OF *T. obscurus* REARED OUTSIDE THE HUMIDIFIER. VALUES ARE GIVEN WITH THEIR STANDARD ERRORS.

Age of parents in days after emergence		Number of larvae	Duration of egg stage in days	Duration of larval stage in days	Number larval molts	Duration of pupal stage in days	Duration of adult life in days
20°C.	7–10	65	7.00*	204.85 ± 3.28	13.48 ± 0.08	12.83 ± 0.09	30.13 ± 1.34
	16	54	7.00*	200.74 ± 2.68	13.19 ± 0.10	13.22 ± 0.08	33.04 ± 1.00
	23	55	7.00*	210.82 ± 3.35	13.31 ± 0.10	13.42 ± 0.10	31.27 ± 1.93
	42	48	7.10*	202.29 ± 3.83	13.69 ± 0.12	12.70 ± 0.08	32.87 ± 3.09
25°C.	7–9	60	7.00	196.67 ± 2.10	14.95 ± 0.09	8.38 ± 0.07	40.10 ± 3·59
	16	52	7.00	191.54 ± 2.88	14.85 ± 0.10	8.37 ± 0.07	30.41 ± 3.17
	23	56	6.00	190.89 ± 2.36	14.75 ± 0.10	8.25 ± 0.07	35.26 ± 2.69
	42	45	7.07	197.44 ± 3.09	15.53 ± 0.10	8.67 ± 0.10	27.25 ± 2.67
30°C.	9	58	7.00*	210.52 ± 3.12	16.17 ± 0.11	6.20 ± 0.07	14.50 ± 0.65
	16	54	7.00*	222.96 ± 3.69	16.94 ± 0.10	6.33 ± 0.07	15.00 ± 0.84
	23	51	7.00*	218.92 ± 3.51	16.84 ± 0.10	6.35 ± 0.07	15.84 ± 0.92
	42	44	7.07*	222.50 ± 3.24	17.43 ± 0.14	6.29 ± 0.08	14.50 ± 0.10

* Eggs laid and hatched at 25°C.

15.38 and 16.99 at 20°, 25° and 30° C., respectively. At each temperature the dark brown color characteristic of the mature larva was attained about the eighth instar.

When those reared in the humidifier were compared with the others, significant differences were obtained for the duration of the larval life, the number of larval molts and the duration of adult life at each temperature (table II). No significant difference was found in the duration of the pupal stage at any of the temperatures.

Figure 1 shows the rate of larval growth at temperatures of 20°, 25° and 30° C. Growth was more rapid the higher the temperature. The average maximal larval weights were also higher at the higher temperatures, being approximately 175, 165 and 100 mg. at 30°, 25° and 20° C., respectively.

The effects of parental age on the life cycle are shown in table III. Parental age did not have any consistent effects on

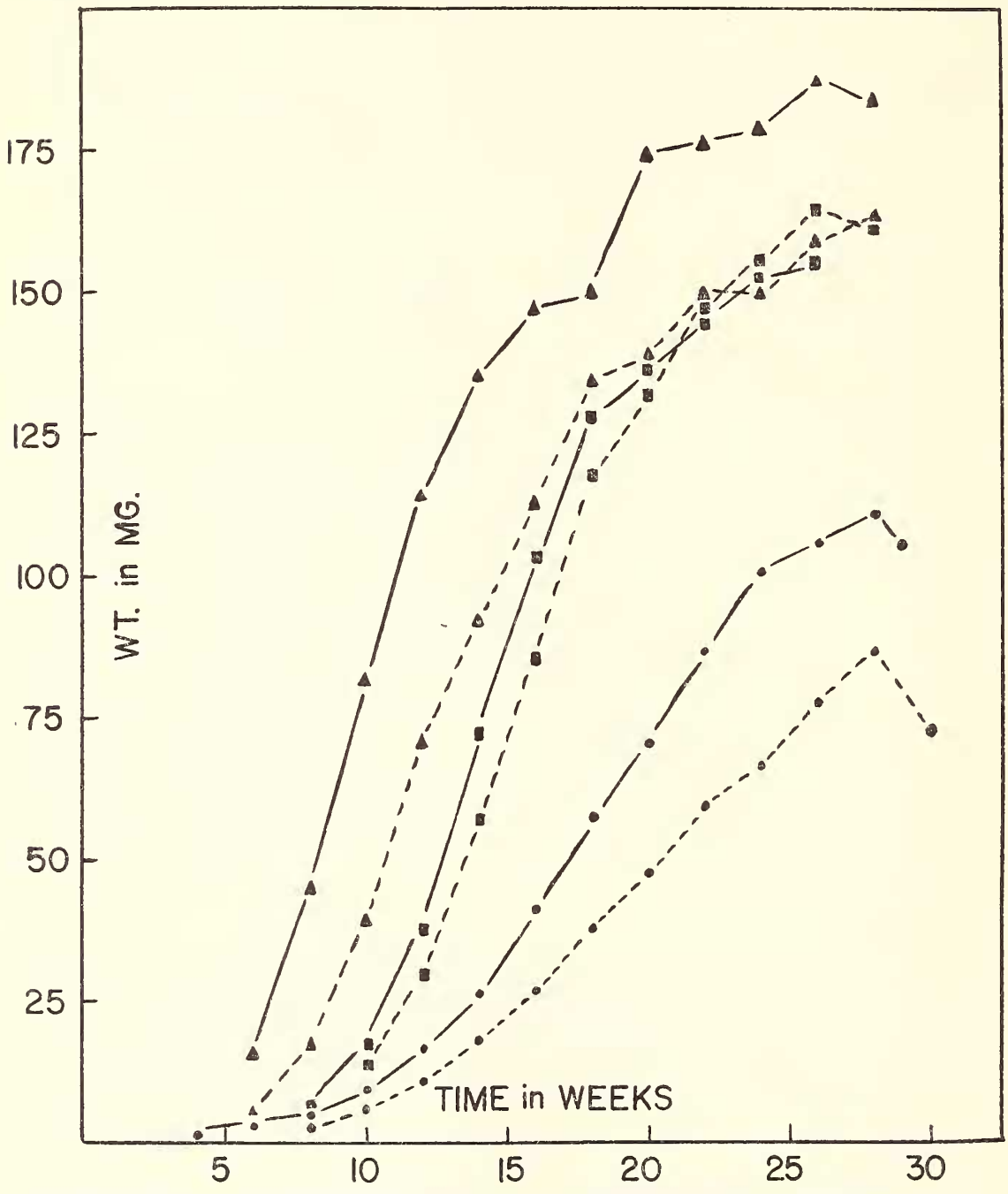

FIG. 2. Effect of parental age on the growth of *T. obscurus* larvae. Circles, larvae at 20°; squares, larvae at 25°; triangles, larvae at 30°C. Solid lines, larvae from parents 7–10 days after emergence; broken lines, larvae from parents 42 days after emergence.

the duration of the life cycle. Parental age, however, did affect the growth rate of the larvae at each temperature. As figure 2 shows, larvae from old parents had a slower rate of growth than those from young parents and, except at 25° C., failed to attain the same maximal weight.

DISCUSSION

In the present experiment, a temperature of 25° C. shortened the duration of the larval stage as compared with that obtained at either 20° or 30° C. It was observed that a few individuals in each group at 30° C. did not pupate properly, being unable to shed the last larval exuviae. Hence, the present experiments are in agreement with those of Arendsen Hein (1923), who found that the optimal temperature for *T. obscurus* is between 25° to 27.5° C. while at 30° C. there was a delayed metamorphosis and an increased larval mortality.

The long larval life in the humidifier may have been due to a diapause which occurred in some individuals, lack of direct water feeding or an inadequate oxygen supply. The humidifiers were opened only once a day so that there was probably an oxygen deficiency, especially for large larvae and adults. Unpublished work in this laboratory on *T. molitor* shows that adding water to the food may hasten growth.

The increase in the number of larval molts obtained at the higher temperatures agrees with the work of Ludwig (1956), who found that the yellow mealworm, *T. molitor,* had more molts at 30° C. than 25° C., the averages being 19.1 and 13.2, respectively. Cotton (1927) observed that *T. obscurus* molted 12 to 22 times, with about half of the larvae molting 14 or 15 times. However, he did not show any temperature effects on molting.

The greater maximal larval weights obtained at higher temperatures agree with the results of Ludwig (1932 and 1939), who found that in the Japanese beetle, *Popillia japonica,* the average weight of the full grown larvae was less at 20° than at 25° C. These results are contrary to the general rule enunciated by Titschack (1925), that insects reared at low temperatures grow to a larger size than those reared at higher temperatures.

Ludwig (1956) and Tracey (1958) showed that larvae of *T. molitor* obtained from old parents had a shorter larval life.

This effect was not found with *T. obscurus*. Tracey (1958) also found that the growth rate was faster in offspring from old parents than in those from young parents. In the present work, parental age affected the offspring in that those from old parents were delayed in their growth rate.

SUMMARY

At each temperature, 20°, 25° and 30° C., the life cycle of the dark mealworm, *Tenebrio obscurus,* was longer when the insect was reared in the humidifier at 75 per cent relative humidity than when it was reared outside the humidifier. This effect may be due to an oxygen deficiency in the humidifier.

Larval life was shortest at 25° C., being 194.06 days outside the humidifier as compared to corresponding figures of 204.77 and 218.38 days at 20° and 30° C., respectively.

The range obtained for the number of larval molts was smallest at 25° C., being 13 to 19 as compared to 12 to 22 and 15 to 24 at 20° and 30° C., respectively.

The duration of adult life was considerably shorter at 30° than at either 20° or 25° C. Outside the humidifier, adults at 30° C. lived less than half as long as those at the other two temperatures.

The rate of larval growth increased with a rise in temperature. Maximal larval weights were also higher at the higher temperatures, being approximately 175, 165 and 100 mg. at 30°, 25° and 20° C., respectively.

Parental age did not have any consistent effects on the duration of the life cycle. However, larvae from old parents had a slower rate of growth than those from young parents.

Literature Cited

ARENDSEN HEIN, S. 1923. Larvenarten von der Gattung *Tenebrio* und ihre Kultur (Col.). Ent. Mitt. 12: 121–159.

COTTON, R. T. 1927. Notes on the biology of the meal worms, *T. molitor* Linne and *T. obscurus* Fab. Ann. Ent. Soc. America 20: 81–86.

——— AND R. A. ST. GEORGE. 1929. The meal worms. United States Department of Agriculture Tech. Bull. 95.

LECLERCQ, J. 1950. Ecologie et physiologie des populations de *T. molitor* L. (Insecte Coleoptere). Physiol. Comp. et Oecol. 2: 161–180.

LUDWIG, D. 1932. The effect of temperature on the growth curves of the Japanese beetle (*Popillia japonica* Newman). Physiol. Zool. 5: 431–447.

———. 1939. The effect of temperature on the size of the columnar cells of the mid-intestine of the Japanese beetle larva (*Popillia japonica* Newman). Physiol. Zool. 12: 209–213.

———. 1956. Effects of temperature and parental age on the life cycle of the mealworm, *Tenebrio molitor* Linnaeus (Coleoptera, Tenebrionidae). Ann. Ent. Soc. America 49: 12–15.

TITSCHACK, E. 1925. Untersuchungen über den Temperatureinfluss auf die Kleidermotte (*Tineola bisselliella* Hum.). Zeitschr. f. wiss. Zool. 124: 213–257.

TRACEY, SR. K. M. 1958. Effects of parental age on the life cycle of the mealworm, *Tenebrio molitor* Linnaeus. Ann. Ent. Soc. America 51: 429–432.